Bradley University

Lithium Ion Medium Power Battery Design

Project Proposal

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Introduction

The objective of this project is to design and implement a medium power Lithium Ion battery with medium capacity for low carbon footprint products. Such products need the capability of storing energy obtained from renewable energy sources such as wind turbines and photovoltaics. The project will utilize Lithium Ion technology due to its high energy density and the predicted increase in availability with decreasing cost. Although Lithium Ion batteries can be currently found in many products from cell phones to electric vehicles, there is a surprisingly limited supply of Lithium Ion batteries that are available for medium power applications. Since the availability is limited but the demand seems to be increasing, it is the goal of this project to meet this growing demand via the design and implementation of a medium power battery module.

Subsystems of the battery module shall include: a battery pack, cell balancing circuitry, switching electronics for protection, and a monitoring system. The battery pack shall consist of Li Ion cells purchased from an industrial vendor that are connected in combinations of series and parallel to best perform in medium power applications. In this case, medium power means supplying 1000W for an hour. Analog and digital electronics will be required for cell balancing and the switching electronics. The monitoring system shall measure and display various parameters, such as charge state, voltage, current, and temperature. Also, it will output this data in useful formats in two separate modes, application mode and test mode.

Finally, a photovoltaic charging system will be designed and implemented to efficiently charge the battery. The charging system will utilize smart-charging techniques to prevent over-charging, as well as offer maximum efficiency for a quick charge. Finally, another major part of the project will be designing the system in compliance with all major standards set by organizations such as IEEE, SAE, and UL.

Project Goals

- Develop effective cell layout interconnection and packaging to yield compact medium power battery with appropriate capacity (1000W for an hour)
- Incorporate a battery management subsystem to:
  - Accurately monitor state of cells during charging and discharging
  - Output data, in various formats, on state of cells
  - Ensure soft failure mode in the event of cell degradation
  - Accept user input as needed
- Implement photovoltaic charging system
- Ensure overall design is in compliance with industry standards

Functional Description & Block Diagram Description

Test mode shall enable the monitoring system to output information for warranty investigation and performance testing of the battery design. This information shall be uploaded to a PC for the manufacturer and will include detailed electrical and physical information. Temperature sensors, voltage taps, and battery charge state measurements shall be used to analyze data. The monitoring system will allow input from the test engineer in order to change displays or data output to allow for quick diagnosis of problems, state of charge of the cells, and the present mode of the system.

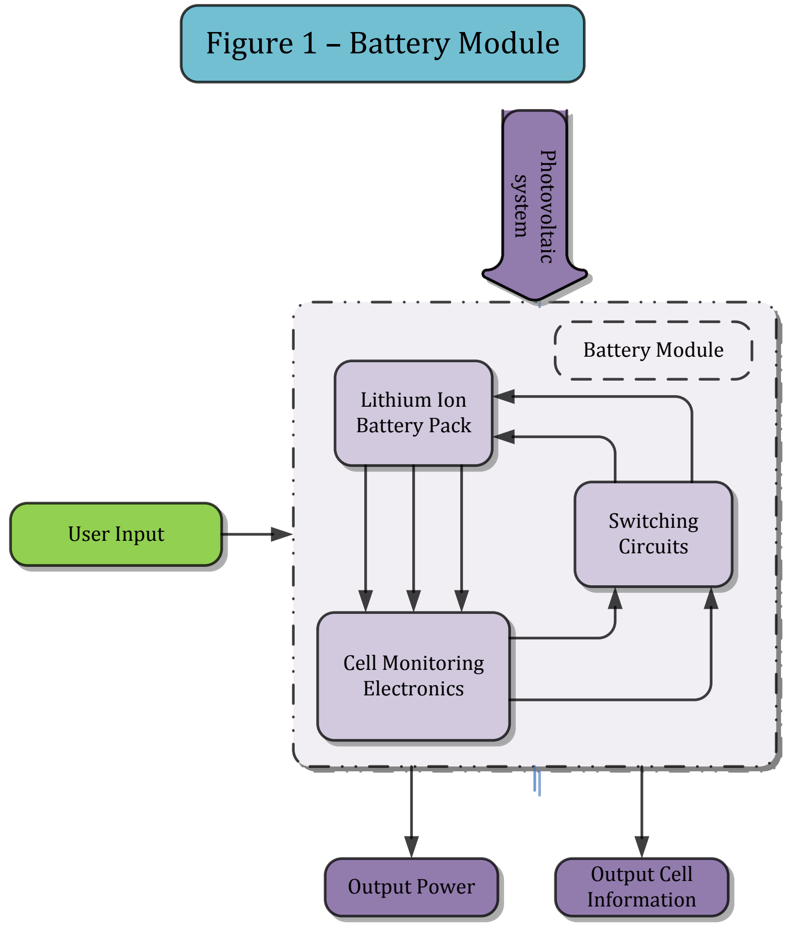
Application mode shall be used by the OEM (Original Equipment Manufacturer) that buys the battery module. The output shall include information useful to the user, such as the overall charge, the time left for proper use, the number of cycles, and a soft failure warning.

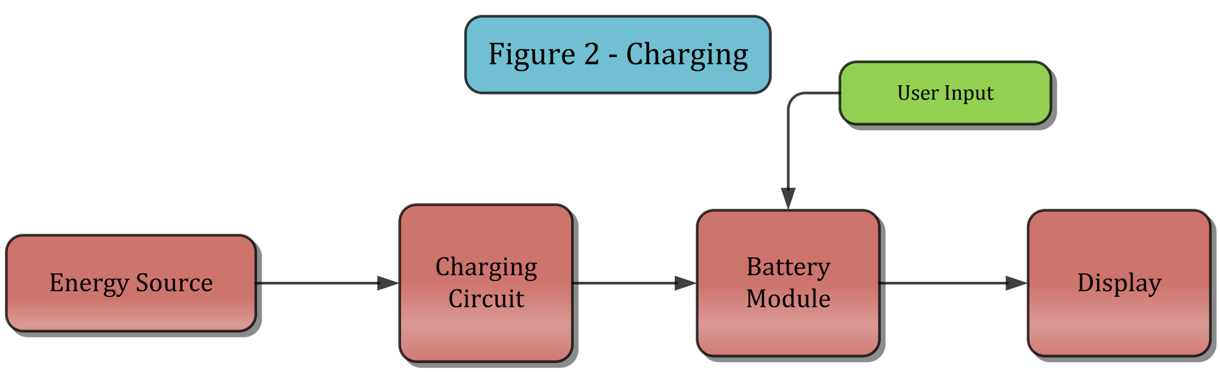
The block diagram for the battery module is shown in Fig. 1 and consists of the battery pack made from individual cells, the cell monitoring electronics, and the switching circuits. As shown, the inputs to the battery module are user inputs and the outputs are cell parameters. Also, the battery will absorb or deliver power depending on if it is being charging or discharged. Finally, the module includes switching circuitry to disconnect cells or cell stacks in case of failure of one or more cells, primarily during discharge.

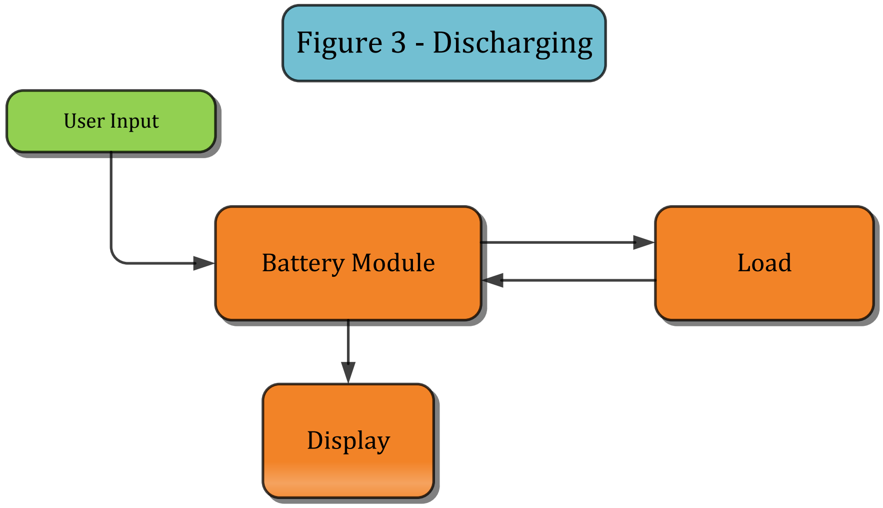
The block diagrams for the charging and discharging stages are shown in Figs. 2 and 3, respectively. In the charging mode, power from an energy source will enter a charging circuit. The charging circuit will regulate the optimum current and voltage going into the battery module to minimize charge time and ensure safe charging. The monitoring electronics inside the battery module will accept a user input to choose information to be shown on the display.

In the discharge stage, the battery module will still accept user input for the display. It will be connected to a load and will supply power to the load, but also will monitor how much current and voltage are going to the load. The battery module will also feed information to update a display for simple user analysis of the system.

Block Diagrams







Functional Requirements & Performance Specifications

The following requirements and performance specifications have been devised and set as realistic deliverables for this system. The system will be designed under the following preliminary specifications:

<u>Physical</u>

- The combined total weight of the module shall be ≤ 13.6 Kg
- The battery module shall measure ≈≤ 50 x 50 x 25 cm.
- The main power connectors on the battery module shall be in the form of threaded posts for compatibility and the ease of making a fast, secure connection.
- The battery module shall meet functional specifications over a temperature range from -20°C ~ 60°C in ambient air.

<u>Electrical [/ *Battery pack*]</u>

- The battery pack shall have a nominal capacity ≈ 60 Ah.
- The battery pack shall supply 1000W at a nominal voltage ≈ 24 V for one hour.
- The battery pack shall have a current discharge limit of 120A for < 10 seconds.
- The battery module shall retain functional specifications over ≥ 1000 charge/discharge cycles.
- It shall maintain compatibility with applicable commercial Lithium Ion chargers.
- The battery shall have protection circuit to ensure that the batteries individual cells cannot reach a temperature exceeding 94°C or can not be charged to a voltage exceeding 3.6V or decrease below 2.8V.

<u>**Electronics** [based on test mode operation]</u>

- The battery module shall include monitoring circuitry accurate to 3%
- The monitoring circuitry shall record the voltage and current flow throughout the battery pack.
- The monitoring circuitry shall upload performance data collected from the multiple sensors to a PC through a USB interface

Datasheet

- Weight => ≤ 13.6 Kg
- Dimensions of module => 50x50x25 cm
- Battery power interface => Threaded Posts
- Operational temperature range => -20°C~60°C
- Nominal capacity => 60 Ah
- Battery supply 1000W/h @ 24V
- Battery max discharge => 120 A < 10 sec
- Battery Life => ≥1000 charge/discharge cycles
- Compatible with commercial Lithium Ion chargers
- Cell voltage limit => 2.8 V ~ 3.6 V
- Monitoring system accuracy ≤3%
- PC interface => USB [Universal Serial Bus]
- Protection Temperature cut-off => 94°C

Standards

Safety is a primary concern when dealing with lithium ion batteries, since there is possibility of fire or explosions if handled or used incorrectly. Underwriters Laboratories and SAE International both have standards pertaining to the safe use of Lithium Ion Batteries. UL has two specific standards that apply to this project: Standard 1642 – Covers requirements for safety in operation and testing pertaining to Lithium ion rechargeable multi-cell batteries, and standard 2054 – Covers requirements for safety in operation and testing pertaining to household and commercial batteries in regards to preventing fires and explosions. SAE International has one applicable standard: AS5679 - Minimum performance standard for Li-Ion rechargeable single and multiple cell batteries. Currently, no publication of this standard is available to the public. J1797 – Recommended practice for packaging of electric vehicle battery modules. This SAE Recommended Practice provides for common battery designs through the description of dimensions, termination, retention, venting system, and other features required in an electric vehicle application. The document does not provide for performance standards. As of 2008, a standard for the characterization of lithium battery technologies in terms of performance, service life and safety attributes is still under development by IEEE with no word on when these will be complete or available to the public

Schedule

		Time		Task - Jeremy
Week	**1**	18-Jan	24-Jan	Research and modeling
Week	**2**	25-Jan	31-Jan	Research and simulation
Week	**3**	1-Feb	7-Feb	Finalize Purchases
Week	**4**	8-Feb	12-Feb	Design Batt. Management sys. based on chipset
Week	**5**	15-Feb	14-Feb	Test Batt. Management sys. based on chipset
Week	**6**	22-Feb	28-Feb	Implement batt. Management sys. Based on chipset
Week	**7**	1-Mar	7-Mar	Implement batt. Management sys. Based on chipset
Week	**8**	8-Mar	14-Mar	Charge & Discharge test on cells
Week	**9**	15-Mar	21-Mar	Charge & Discharge test on series combinations
Week	**10**	22-Mar	28-Mar	Charge & Discharge test on parallel Combinations
Week	**11**	29-Mar	4-Apr	Implement and test an 8 series Stack w/ Batt. Management
Week	**12**	5-Apr	11-Apr	implement 2nd & 3rd 8 series stack
Week	**13**	12-Apr	18-Apr	implement Battery Pack & Test for Specifications
Week	**14**	19-Apr	25-Apr	Prepare final project report
Week	**15**	26-Apr	2-May	Prepare Presentation
Week	**16**	3-May	9-May	Presentation
Week	**17**	10-May	16-May	Presentation
				NOTE: Subject to Variation

(Buchmann)

		Time		Task - Charlie
Week	**1**	18-Jan	24-Jan	Research Lab Charger
Week	**2**	25-Jan	31-Jan	Research => Purchase Lab Charger
Week	**3**	1-Feb	7-Feb	Research Charging Circuit Topologies
Week	**4**	8-Feb	12-Feb	Design => Test => Implement Charging Circuit
Week	**5**	15-Feb	14-Feb	Design => Test => Implement Charging Circuit
Week	**6**	22-Feb	28-Feb	Purchase & Test USB interface subsystem
Week	**7**	1-Mar	7-Mar	Purchase & Test USB interface subsystem
Week	**8**	8-Mar	14-Mar	Charge & Discharge test on cells
Week	**9**	15-Mar	21-Mar	Charge & Discharge test on series combinations
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References

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